Quantity of plant leaf area on three major public squares in Kunming City, China

DONG Yan [1], ZHAO Lin-sen [1*], ZHAO Yu-xiang [2]

[1] *Faculty of Landscape Architecture, Southwest Forestry College, Kunming 650224, P. R. China*

[2] *General Station of Forest Pest Control, National Bureau of Forestry, Shenyang 110034, P. R. China*

Abstract: Regressive formulae to calculate the quantity of plant leaf area for 13 species of ornamental plants were set up based on investigation data of 30 species on 3 major public squares (Dongfeng square, Shengli square and Guandu square) in Kunming City, China, which were applied to calculate quantities of plant leaf area of these 13 species. The quantities of plant leaf area for the other 17 ornamental plant species on these squares were directly measured, and the total quantity of plant leaf area of each studied square was obtained individually. The results showed that the quantity of plant leaf area on Shengli square with ornamental plants structure composed of arbor tree species, shrub tree species and turf grass was highest among the three squares. It is believed that the design model of multi-storied vertical structure and proper tending of plant community could not only increase the quantity of plant leaf area, but also play an important role in generating ecological and landscaping benefits. Some corresponding suggestions were put forward on the basis of comprehensive analyses on the plant leaf area quantity of the three representative squares in Kunming urban area.

Keywords: Square; Ornamental plants; Quantity of plant leaf area; Kunming

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Introduction

Quantity of plant leaf area is an index, which is newly put forward to evaluate the greening standard along with the theory development of ecological cities and towns, and it is a supplement or perfection to existing indices for greening assessment (Chen *et al.* 1998). The quantity of plant leaf area is a decisive factor that determines the ecological benefits produced by green-space in urban areas, and an important indicator of greening effect in modern cities. To improve spatial allocation of ornamental plants and to increase the quantity of plant leaf area of green-spaces are effective approaches to enhance the greening area in the center of a city or a town (Chen *et al.* 1998). Rational calculating the quantity of plant leaf area is essential in evaluating ecological benefits of green-spaces and assessing the afforestation level of a city or a town, which is greatly determined by the species composition and spatial disposition of the ornamental plants (Huang *et al.* 1998a; Huang *et al.* 1998b; Zhou *et al.* 1998; Qi *et al.* 2002).

A number of researches have been done abroad on calculating plant leaf area quantities of different tree species, which were important foundation for quantitative study on benefit-cost analysis of urban forests. Some similar studies have been carried out in past few years in Beijing, Shanghai, Shenyang, Harbin and other cities in China. So far, few works likewise were done in Kunming City, Yunnan Province. On the basis of summarizing characteristics of public squares in urban areas of Kunming City, ornamental plants on three typical public squares, i.e., Dongfeng, Shengli and Guandu squares in Kunming, Yunnan Province were sampled and investigated and regressive models for the major plant species were eventually set up for calculating plant leaf area quantities. It is believed that the results of this kind of research might have supplied a reasonable foundation for further quantitative study on ecological benefits of green-space and on benefit- cost analysis of urban forest in Kunming urban area.

Generalization of studied area

Kunming City is situated in the central area of the eastern Yunnan plateau with elevation of 1891 m above sea level. The climate in Kunming is influenced by the oceanic monsoon of South Bangladesh Bay and warm moist current from Northern Bay of Southeast Asia and is typical subtropical climate with moderate variations in temperature around the year.

The 30 species of ornamental plants, including 19 arbor tree species and 11 shrub tree species were studied on the quantity of plant leaf area.

Dongfeng square that is one of three squares studied is located in central east of Kunming urban area. The total area of the square was 30 240.1 m^2, among which 12 107.17 m^2 was green-space area, and the greening ratio of the square was 40.04%. The plantation type on the

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Biography: DONG Yan (1978-), female, Graduate student in Faculty of Landscape Architecture, Southwest Forestry College, Kunming 650224, P. R. China. (E-mail: fswallow0609@163.com)

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* **Corresponding author**: E-mail: zhaols@public.km.yn.cn

square was typical two-storied planting model composed of arbor trees and turf grasses vegetation.

Shengli square is located in the center of Kunming City. The total area of this square was 5 972.00 m^2, with 3 670.67 m^2 of green-space, and the greening ratio of the square was 61.46%. The planting model on this square was typically vertical plantation composed of arbor tree species, shrub tree species and turf grass layers.

Guandu square lies in southeastern suburban area of Kunming City. The original planting model designed for this square was a vertical structure combined with arbor tree species, shrub tree species and turf grass, but the grasses of groundcover layer were heavily damaged due to selecting the improper species and poor management. And then the actual plantation model was only composed of arbor tree species and shrub tree species. The total area of Duangdu square was 10 062.45 m^2, with 1 331.38 m^2 of green-space, and the greening ratio was 13.23%.

Study methods

Measurement of square areas

Each square perimeter of the three squares was measured, the plane figures of the squares were drawn by the computer with AUTOCAD software, and total areas and areas of green-space for each square were calculated.

Investigation of ornamental plants

Indices of tree species, such as number of plants for each species, height, basal diameter, diameter at breast height (DBH) and health condition of each plant were observed on each of the three squares, respectively. The health condition of the trees were classified into four grades, i.e., grade Ⅰ stands for being healthy, grade Ⅱ stands for being normal, grade Ⅲ stands for being poor, and grade Ⅳ stands for dying out.

Sampling

Ten sample trees were selected as standard plants for each tree species on each square according to the average level of above indices for measuring and calculating plant leaf area quantities.

Measurement of leaf area

The medium sized leaves were selected to measure leaf area for each tree species with different formed leaves. Every ten needle or thorn formed leaves were selected and fixed together for measuring the total surface area of the ten leaves, and then total surface area was divided with ten to get the area of each needle or thorn (Qi *et al.* 2002). The leaves of cedar (*Cedrus deodara*) were in column form, therefore the formula to calculate the surface area of a column body was applied to measure the leaf area of cedar. Surface area of scale-formed leaves, as platyclados (*Platycladus orientalis* cv. Aurea nana) was measured by grid method, and the leaf area of deciduous tree species was measured by pin-holing and weight measuring method.

Quantity of leaves

Criterion branch method

Since the number of leaves on sunny side of a tree is more than that of on the shady side, the crown of each sampled plant was vertically divided into sunny and shady for two semi-spheres crowns. One standard branch with medium quantity of leaves was selected from each semi-spheres crown, and the number of leaves on each standard branch was counted respectively and the mean of leaves on two standard branches was taken as the average number of leaves for an average branch of this plant. The number of branches resembling the average branch was counted, and then the total number of leaves of this tree was the number that the leaf number of the average branch multiplied by the number of average branches.

Unit volume method

This method was mainly applied to shrub species that plants were trimmed or pruned heavily and the original crown shape had been lost. Five to ten cubic samples with volume (10 cm×10 cm × 10 cm or 20 cm×20 cm × 20 cm) were taken among the trimmed crown where the leaf quantities and leaf growth status were representative, and the number of leaves per cubic sample was calculated on the basis of averaging leaf numbers within each sampled cubic volumes (Chen *et al.* 2002). Then the total volume of the trimmed crown was calculated according to the trimmed shape, and the total leaf quantity of the crown was got by multiplying the average leaf number of each cubic sample by the number of cubic volumes.

Calculation of plant leaf area quantity

As described above, the plant leaf area quantity of each sampled plant was calculated by multiplying average area of each leaf by the number of the leaves on a certain plant. The quantities of plant leaf area on each of the three sampled public squares were calculated thereafter. Besides, regressive formulae for major plant species on three squares were modeled in the light of the correlations among the leaf area, DBH, height and diameter of the crown (Chen *et al.* 1998), (Table 1). For the clumped growing shrubs, total quantity of plant leaf area was calculated for the plant groups. The leaf area index (LAI) for grass land was between 1.7 and 3.0, and the quantity of plant leaf area per square meter of green-space on grass land was 2.35 $m^2 \cdot m^{-2}$ (Cai *et al.* 2002).

Result and analysis

Growth status of plants on three squares

The proportional ratios (i.e., grades Ⅰ : Ⅱ : Ⅲ: Ⅳ) of plant growth status on the three studied squares were as follows: On Shengli square : 33.76 : 61.57 : 4.25 : 0.42; On Dongfeng square : 56.52 : 28.26 : 13.04 : 2.17; On

Guandu square: 59.85 : 34.20 : 5.58 : 0.37.

The results showed that over 95% of the plants on Shengli square grew well, which was related to the vertical plantation structure composed of arbor tree species, shrub tree species and turf grasses. Less than 85% of plants on Guandu square grew well, 13.04% of plants were in poor health, and 2.17% of plants were dying because of the simple structure and poor management. About 94% of plants grew well on Guandu square because most of the arbors and shrubs were native species

Table 1. Regressive models of plant leaf area quantity for major plant species on three squares in Kunming City

Major plant species	Regressive model of plant leaf area quantity	Regressive model of plant leaf area quantity
Cinnamomum glanduliferum(Wall.)Ness	S=4.7106W-13.5440	R^2=0.7033
Elaeocarpus decipiens Hemsl.	S=1.6658W-6.3881	R^2=0.9209
Acer palmatum	S=29.2050Q-26.8080	R^2=0.6647
Chamaecyparis obtuse cv. Filicoides	S=14.2620Q-4.1138	R^2=0.7643
Cycas revolute Thunb.	S=10.5940K-3.1664	R^2=0.5916
Ficus benjamina L.	S=18.3950K+20.002	R^2=0.8048
Magnolia grandiflora L.	S=13.2770W-108.31	R^2=0.8364
Edgeworthia chrysnatha Lindl.	S=12.5930Q-11.0170	R^2= 0.7604
Prunus ameniaca Linn.	S=8.7008W-32.8190	R^2=0.9928
Lagerstroemia indica L.	S=3.7199W-17.9470	R^2=0.7174
Grevillea robusta Gunn.	S=8.4989W-113.8000	R^2=0.5312
Koelreuteria bipinnata Franch.	S=24.3940W-229.4700	R^2=0.8364
Phobe zhennan S.Lee et F.N.Wei	S=16.0000W-202.1900	R^2=0.5060

Notes: Q stands for crown diameter; W stands for DBH; K stands for crown height

Table 2. Planting model and the quantity of plant leaf area on three Squares in Kunming City

Square	Structure	Plant type	Number of plants	Area/m²	Quantity of plant leaf area/m²	Proportion of the total plant leaf area quantity (%)
Shengli square	Upper layer	Arbors	108		1608.84	6.22
	Intermediate layer	Shrubs	363		2533.31	10.00
		Hedge		122.27	12976.08	50.21
	Ground layer	Meadow		3670.67	8626.08	33.38
	Total				25843.81	
Dongfeng square	Upper layer	Arbors	92		16985.60	36.37
	Intermediate layer	Hedge		101.52	1264.53	2.71
	Ground layer	Meadow		12107.17	28451.86	60.92
	Total				46701.99	
Guandu square	Upper layer	Arbors	154		3922.07	30.46
	Intermediate layer	Shrubs	75		3648.32	28.34
		Hedge		578.95	3925.56	30.49
	Ground layer	Meadow		586.18	1377.52	10.71
	Total				12873.47	

From Table 2, the total area of Shengli square was the smallest of the three for 5 972.00 m^2, the green-space area was 3 670.67 m^2, and the greening ratio of the square reached 61.46%. The planting model was a typical vertical structure composed of arbor tree species, shrub tree species and turf grasses, including 18 species of plant, 108 arbors, 363 individually grown shrubs, hedge of 122.27 m^2 and meadow of 3 670.67 m^2. Therefore, the multi-layered structure provided rich biodiversity and great quantity of plant leaf area on the square. The total of plant leaf area quantity of the square was 25 843.81 m^2, and the medium quantity of plant leaf area per unit land area was 4.33 $m^2 \cdot m^{-2}$. The total of plant leaf area quantity was mainly produced by shrubs and meadow plants.

The total area of Dongfeng square was the largest one among the three squares for 30 240.10 m^2, the green-space area on this square was 12 107.17 m^2, and the greening ratio was 40.04%. As the square was situated in the central part of Kunming, the traffic discharge and flow of moving people around the area were greater than the other two squares. In order to provide wide green-space, the planting model was composed of tall arbor tree species and groundcovers. There were 9 plant species including 70 stems of arbors, hedge of 101.52 m^2 and meadow of 12 107.17 m^2. The total quantity of plant leaf area was 46 701.99 m^2, and the medium quantity of plant leaf area per unit land area on Dongfeng square was 1.54 $m^2 \cdot m^{-2}$.

Since the groundcover, i.e., grasses were severely damaged, the planting structure of green-space on Guandu square was actually composed of arbor tree species and shrub tree species, and the earth was commonly exposed in the air. The total area of the square was 10 062.45 m^2,

while the green-space area was only 1 331.38 m^2, and the greening ratio of Guandu square was 13.23%. The total quantity of plant leaf area was 12 873.47 m^2, and the average plant leaf area quantity per unit land area on Guandu square was 1.28 $m^2 \cdot m^{-2}$.

Table 3. Multiple comparisons of the green-spaces on three public squares in Kunming City

Name of squares	Total area/m^2	Green-space area /m^2	Greening ratio (%)	Total quantity of plant leaf area/m^2	Plant leaf area quantity per unit land area/ $m^2 \cdot m^{-2}$
Shengli	5972.00	3670.67	61.46	25843.87	4.33
Dongfeng	30240.10	12107.17	40.04	46701.99	1.54
Guandu	10062.45	1331.38	13.23	12873.47	1.28

Conclusions

Order of the average quantity of plant leaf area per unit land area on the studied three public squares was as Shengli> Dongfeng>Guandu square. The total area of the Shengli square was the smallest among the three squares; however, both the coverage green-space area and the quantity of plant leaf area per unit land area of Shengli square were the biggest of the three. Though the quantity of plant leaf area is closely related to green-space coverage, planting model and vegetation allocation are more important in determining the quantity of plant leaf area on a specific locality. The plantation on Shengli square was composed of arbor tree species, shrub tree species and turf grasses, which not only enriched the landscape stratification, but also improve stability of the community, increase the quantity of plant leaf area to a great extent at the same time, and it was beneficial to either landscape effects or ecological benefits of the community. The plantation model on Guandu square was represented by arbor tree specie with shrub tree species, which also had some layering structure and biodiversity in tree species. However, the quantity of plant leaf area per unit land area was smaller, and consequently the ecological benefits produced were reduced greatly. Comparatively speaking, the planting model on Dongfeng square was arbor tree species combined with grasses, which offered poorer landscape, weaker stability and less ecological benefits. The results showed that arbors, shrubs and grasses should be proportionally arrayed in a plantation community of green-space to meet the multiple demands of public squares and to avoid the improper tendencies of either planting too many arbor trees or growing too much pure turf grasses in greening of public squares.

The ecological benefits of plants to improve environmental quality are brought about in the process of substance circulation and energy flow inside the leaves; therefore, the plant leaf area quantity is a key factor to determine the ecological benefits, and also a supplemented index in evaluating the greening effect in urban area.

Suggestions

(1) In the light of making full use of the limited space, we must pay more attention to the rational utilization of arbor tree species that are the major parts of the quantity of plant leaf area when public squares are designed. The multi-storied vertical structure with arbor tree species, shrub tree species and turf grass species can provide larger quantity of plant leaf area in the green space.

(2) According to the climatic features in Kunming City, and growth characteristics of landscaping tree species, more suitable species of ornamental plants should be taken into consideration to increase greater plant leaf area quantity and to develop proportionally vertical greening structure for enhancing the total quantity of plant leaf area on the green-spaces of public square.

(3) Since the plant leaf area quantity is significantly influenced by the health condition of plants, plant management of green-space on public squares should be strengthened and the living environment of ornamental plants should be improved for healthy plants growth in order to form the maximum quantity of plant leaf area for supplying optimal ecological benefits.

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